Review on continental Permo-Carboniferous deposits in Italy

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ABSTRACT
The paper presents a short, but up-to-date review of the late Paleozoic to Triassic continental deposits of a large part of Italy. These deposits generally crop out in northern Italy, from the Dolomites to the western Alps, in some central and maritime zones of Tuscany, and, much further south, in Calabria and NE Sicily. Since the tectonics of these regions are highly complex, the stratigraphic schemes drawn up in figures 2, 3 only show the most complete and significant lithological successions. From the results, it is worthy of note that the (late)-postHercynian continental sequences under discussion can generally be divided into two main tectonosedimentary cycles. The lower cycle consists both of alluvial-lacustrine siliciclastic deposits and of calcalkaline acidic-to-intermediate volcanic products. On the whole, this cycle ranges from Late Carboniferous to Late Permian times. In the Alps, the overlying cycles includes the well-known Verrucano-Val Gardena clastics, which are still Permian in age. However, the Apenninic Verrucano is younger, generally pertaining to the Middle Triassic.

KEY WORDS
sedimentary continental deposits,
volcanic products,
plutonic bodies,
(late)-postHercynian
metamorphism,
tectonosedimentary cycles,
Upper Carboniferous,
Permian,
Triassic p.p.,
southern and western Alps,
Tuscany,
"Calabro-Peloritan Arc".

RÉSUMÉ

Ce papier présente un bref résumé, qui est une mise à jour des dépôts continentaux d'Italie du Paléozoïque au Trias. Ces dépôts affleurent généralement en Italie du Nord, des Dolomites aux Alpes occidentales, dans quelques zones centrales et maritimes de Toscane, et plus loin vers le sud, en Calabre et dans le NE de la Sicile. La tectonique de ces zones étant très complexe, les schémas stratigraphiques (Figs 2, 3) ne montrent que les successions lithologiques les plus significatives et les plus complètes. Cependant, dans cette revue, de nombreuses données sur les dépôts du Carbonifère et du Permien concernent les régions voisines. À partir de ces résultats, il est intéressant de noter que les séquences (tardi-) post-hercyniennes peuvent généralement être subdivisées en deux cycles tectonosédimentaires principaux. Le cycle inférieur consiste à la fois en des dépôts alluvio-lacustres silicoclastiques et en produits de volcanisme pour la plupart intermédiaire à acide calco-alcalin. L'ensemble de ce cycle s'étend du Carbonifère supérieur au Permien tardif. Dans les Alpes, le cycle susjacent inclut les dépôts détritiques du Verrucano et de Val Gardena, d'âge encore permien. Le Verrucano apennin, est cependant plus jeune, et appartient généralement au Trias moyen.

MOTS CLÉS
dépôts continentaux,
Paléozoïque supérieur à Trias,
Italie.

After the tectonic-metamorphic events of the Hercynian orogeny, the present north-western part of Italy, which ranges approximately from the eastern Dolomite Alps to southern, coastal Tuscany, together with the "Calabro-Peloritan Arc", represented primarily continental domains, where siliciclastic and/or magmatic deposits developed in various ways, right up to the diachronous Triassic marine transgression.

UPPER CARBONIFEROUS

Well-documented Upper Carboniferous successions, which lie unconformably on the Hercynian crystalline basement, crop out in some sectors of the Italian Alps (Como-Maggiore region, western Liguria) and in the northern Apennines (Mts. Pisani, Jano village), and extend to fairly adjacent regions. They generally mark the beginning of a cycle, where the annexed deposits also include the Permian (Italian I.G.C.P. 203 Group 1986; Cassinis *et al.* 1988).

Southern Alps

The scattered, strip molasse outcrops of Manno and Logone, which lie unconformably on the Hercynian crystalline basement of the South Alpine segment, are rich in fossil plants, and constitute the best-known example of the central sector of this chain. Jongmans (1960) identified *Linopteris neuropteroides*, *Pecopteridium*, *Sigillariaephyllum*, *Cordaites* cf. *borassifolius* in the former locality, near Lugano, and classified the flora as middle or B-C Westphalian; Venzo & Maglia (1947) ascribed the latter deposits of the Alpe Logone to Westphalian C, on the basis of the presence of *Calamites* spp., *Pecopteris plumosa*, *Linopteris neuropteroides*, *Lepidodendron weltheimi*, abundant *Sigillariae* and other plants. Nearby, however (*e.g.* in Bedero, on the eastern side of Lake Maggiore), the presence of scarse Stephanian clastic strata and small anthracite lenses has also been generally recognized.

To the west, in the South Alpine lower crust of the Ivrea Zone, the LP-HT granulitic series, with basic and ultrabasic meta-intrusives, date back to about 300 Ma (*e.g.* Pin & Vielzeuf 1983; Pin 1986).

Western Alps

Within the boundaries of the extensively metamorphic western Alps, and as far as the Ligurian segment, the inner lower Austroalpine domain of the Sesia-Lanzo Zone shows the intrusion of a number of (late)-postHercynian granitoid and mafic-igneous bodies. Possible Carboniferous

and Permian detrital sediments, accompanied by intermediate-to-acidic calcalkaline volcanics, are also recorded in the Dent Blanche nappe, near the Switzerland-Italy border (Ayrton *et al.* 1982). In the Pennine areas, both internal sectors (Mount Rosa, Gran Paradiso, Dora Maira) and external sectors (Briançonnais, Gran S. Bernardo) seem to be widely characterized by Carboniferous and Permian clastic sediments, which are still associated with volcanic rocks. (Late)-postHercynian

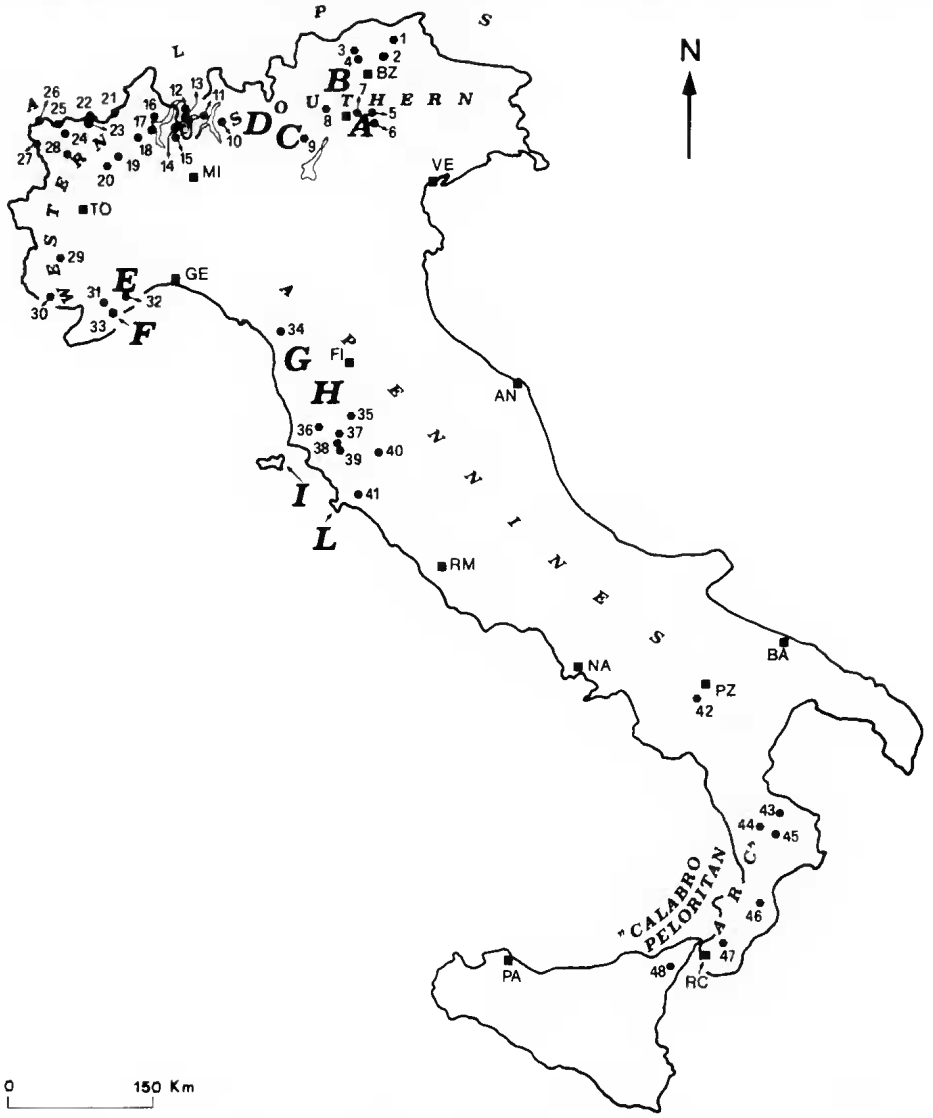


FIG. 1. — Map location. Big letters: stratigraphic sections showed in Figs 2, 3. **A**, Val Fersina Section; **B**, Tregiovo Section; **C**, Val Trompia Section; **D**, Val Seriana Section; **E**, Mallare Section; **F**, Case Tuberto Section; **G**, Mt. Pisani Section; **H**, Iano Section; **I**, Elba Section; **L**, Argentiario Section. Numbers: localities cited in the text. **1**, Rio di Pusteria; **2**, Bressanone; **3**, Mt. Ivigna; **4**, Giogo della Croce; **5**, Cima d'Asta; **6**, Val Sugana area; **7**, Val Fersina area; **8**, Dosso del Sabion; **9**, Basse Giudicarie area; **10**, Val Biandino; **11**, Alpe Logone; **12**, Manno; **13**, Lugano; **14**, Cuasso al Monte; **15**, Varese; **16**, Montorfano; **17**, Baveno; **18**, Roccapietra; **19**, Biella; **20**, Ivrea; **21**, Mt. Rosa; **22**, Matterhorn (Cervino); **23**, Dent Blanche area; **24**, Aosta; **25**, Passo del Gran San Bernardo; **26**, Mt. Bianco; **27**, Passo del Piccolo San Bernardo; **28**, Gran Paradiso; **29**, Dora Maira area; **30**, Cima dell'Argentera; **31**, Ormea, **32**, Mallare, **33**, Case Tuberto; **34**, Alpi Apuane area; **35**, Siena, **36**, Larderello; **37**, Monticiano; **38**, Roccastrada; **39**, Mt. Leoni; **40**, Mt. Amiata; **41**, Mts. Romani; **42**, Mt. Facito; **43**, Longobucco; **44**, Sila area; **45**, Rovale; **46**, Serre area; **47**, Aspromonte area; **48**, Mts. Peloritani area.

intrusives, including granitoids and subordinate gabbro-dioritic bodies, also crop out.

Upper Paleozoic units in the Helvetic (or Dauphinois) Zone *s.l.* of the western Alps occur in the upper Val d'Aosta and in surrounding Swiss and French territory. Huge intrusions (*e.g.* Mt. Bianco granite: 316 Ma, Bussy *et al.* 1989) took place during Carboniferous times. Along the Italian slope of the Argentera massif, a few Westphalian-Stephanian rock-sequences, lying unconformably on the basement, crop out locally. Radiometric age-dating of the Argentera central core granite and other rocks (286-293 Ma, according to Ferrara & Malaroda 1969), which intrude the pre-Westphalian metamorphic complex, is largely in agreement with the age suggested by the afore-mentioned Upper Carboniferous cover.

In the western Ligurian Alps, the Upper Carboniferous is well-known, and again consists of continental metavolcanics and metasediments (Cortesogno *et al.* 1988). In the external Briançonnais (Fig. 2), the (Late)-postHercynian sequence, which rests unconformably upon a pre-Namurian crystalline basement, commences with some detrital deposits and calcalkaline rhyolitic ignimbrites, which are also widespread in the internal sectors. Granitic dikes, and subvolcanic and intrusive granitoid bodies, which are probably connected with this early magmatic phase, occurred at different crustal levels. Later on, fluvial to lacustrine, coarse- to fine-grained, clastic sediments and local graphitic lenses, as well as rhyolitic and andesitic eruptive products, were deposited within fault-bounded basins, which persisted up to Late Permian times. Among these sedimentary units, the Ollano Formation (Fig. 2), at most 1000 m thick, represents the lateral equivalent of the French "Houillère" Zone. Moreover, the ubiquitous andesitic, tuffaceous and lava flow products (Eze Formation), which characterize the Late Paleozoic middle volcanic episode of the Ligurian Briançonnais domain, display a subalkaline potassic series with calcalkaline affinity (Cortesogno *et al.* 1992). A number of fossil plants, identified as *Pecopteris plumosa dentata*, *Sphenopteris schatzlarensis*, *Imparipteris* (*Neuropteris*) *obliqua*, etc. (Bloch 1966), classified the afore-mentioned deposits as upper Westphalian-Stephanian (Cerro *et al.* 1969) and possibly slightly younger Permian (Vanossi 1991).

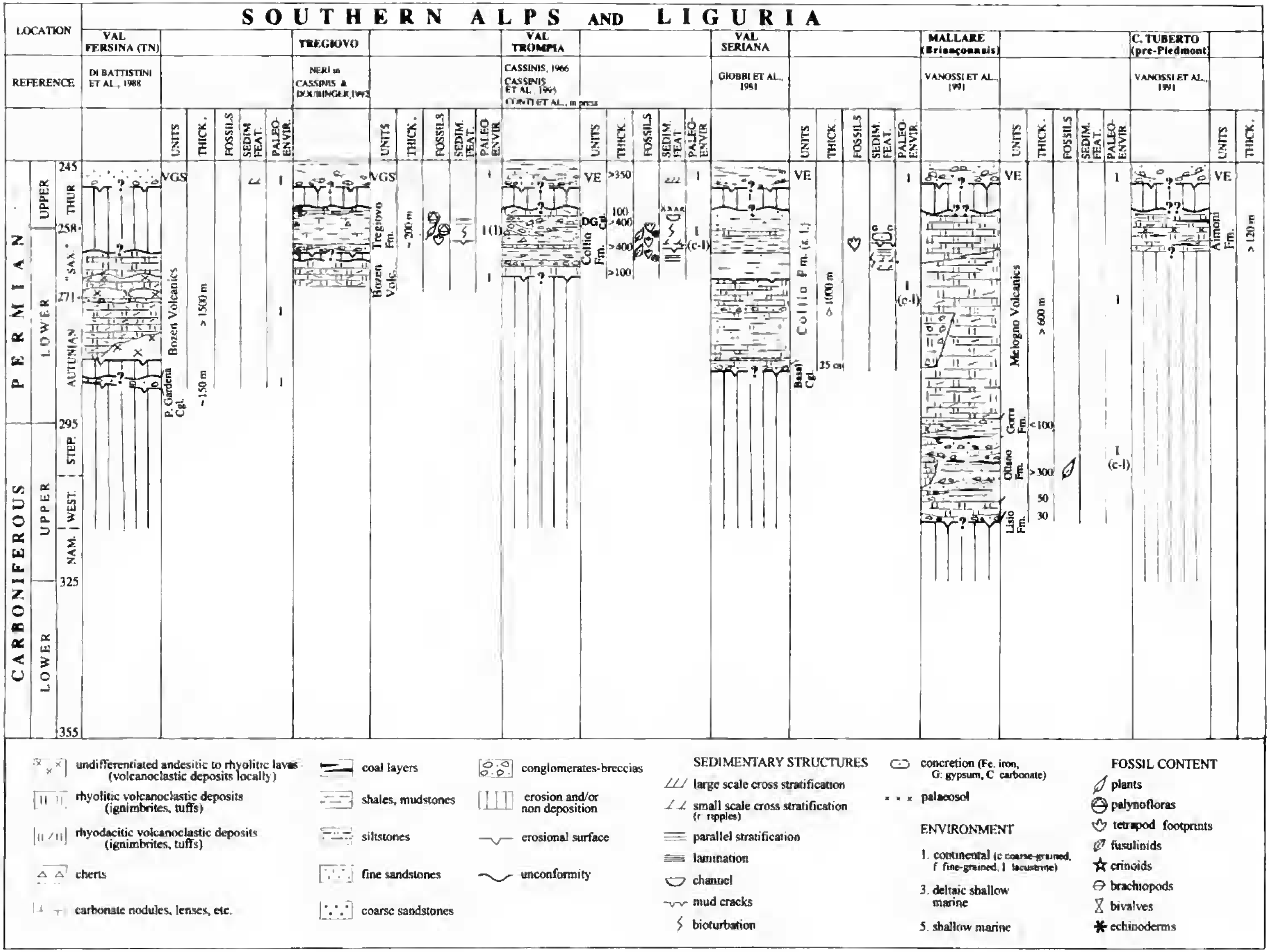
Apennines

In the Apennines, Upper Carboniferous outcrops are well-known in the north-eastern Pisan Mts. and near Jano, south of the Arno River. In the former area (Fig. 3), the San Lorenzo Schists consist of black silty shales, with graphitic layers, which gradually pass, in the uppermost part, to coarse-grained sediments, which can be as much as 300 m thick, and are rich in plant fossils ranging from Wesrphalian D (?) to Early Permian (Remy *in* Rau & Tongiorgi 1974). Pelecypods, ostracods and insects also occur. The crystalline substrate should occur below this unit.

The (Late)-postHercynian, weakly metamorphosed, lower sequence of Jano (Fig. 3), south of Volterra, is essentially made up of alluvial-deltaic sandstone and dark-grey shales, which are a few dozen meters thick, and include plant remains and shallow marine organisms, such as crinoids, pelecypods and possibly brachiopods (Iano Formation). The flora has been identified by Vai & Francavilla (1974) as belonging to the Stephanian A.

Marine influences were also reported for the Island of Elba, where a Permo-Carboniferous, tectonized and slightly metamorphic succession of dark-grey detrital sediments and graphitic levels crops out near Rio Marina, along the eastern coast (Fig. 3). These rocks yield pelecypods, crinoids, echinoids, brachiopods, fusulinids [referred to as *Parafusulina* (Bodechtel 1964; Kahler & Kahler 1969)] and plant remains. Vai (1978) suggested that these fossil-bearing beds range from near the Westphalian-Stephanian boundary to the Early Permian. The unit has been interpreted as a prograding deltaic deposit. Further south, the Mt. Calamita Schists perhaps represent a more metamorphic equivalent of the Rio Marina Formation (Vai 1978).

Fig. 2. — Some selected and schematic Upper Carboniferous-Permian continental successions in the Italian Alpine regions (localities in figure 1). Abbreviations: **VGS**, Val Gardena Sandstones; **VE**, Verrucano Lombardo. Vertical distances not time or thickness-related. Geologic time scale from Odin & Odin (1990).


SOUTHERN ALPS AND LIGURIA
LOCATION
REFERENCE
VAL FERSINA (TN)
DI BATTISTINI ET AL., 1988
TREGIOVO
NERI in CASSINIS & DOUBINGER 1992
VAL TROMPIA
CASSINIS, 1966
CASSINIS ET AL., 1995
CONTI ET AL., in press
VAL SERIANA
GIOBBI ET AL., 1981
MALLARE (Briançonnais)
VANOSSI ET AL., 1991
C. TUBERTO (pre-Piedmont)
VANOSSI ET AL., 1991
UNITS
THICK.
FOSSILS
SEDIM. FEAT.
PALEO-ENVIR.
PERMIAN
CARBONIFEROUS
UPPER
LOWER
THUR
"SAX."
AUTUNIAN
STEP.
WEST.
NAM.
245
258
271
295
325
355
VGS
VE
DG
Bozen Volcanics
P. Gardena Cgl.
> 1500 m
~ 150 m
Tregiovo Fm.
Bozen Volc.
~ 200 m
Collio Fm.
Cgl.
>350
100 - 400
>400
>100
Collio Fm. (s. l.)
Basal Cgl.
> 1000 m
25 cm
Melogno Volcanics
Gorra Fm.
Ollano Fm.
Lisio Fm.
> 600 m
<100
>300
50
30
Aimoni Fm.
> 120 m
undifferentiated andesitic to rhyolitic lavas (volcanoclastic deposits locally)
rhyolitic volcanoclastic deposits (ignimbrites, tuffs)
rhyodacitic volcanoclastic deposits (ignimbrites, tuffs)
cherts
carbonate nodules, lenses, etc.
coal layers
shales, mudstones
siltstones
fine sandstones
coarse sandstones
conglomerates-breccias
erosion and/or non deposition
erosional surface
unconformity
SEDIMENTARY STRUCTURES
large scale cross stratification
small scale cross stratification (r: ripples)
parallel stratification
lamination
channel
mud cracks
bioturbation
concretion (Fe: iron, G: gypsum, C: carbonate)
palaeosol
ENVIRONMENT
1. continental (c: coarse-grained, f: fine-grained, l: lacustrine)
3. deltaic shallow marine
5. shallow marine
FOSSIL CONTENT
plants
palynofloras
tetrapod footprints
fusulinids
crinoids
brachiopods
bivalves
echinoderms

Along the Tuscan Maremma, in the southeastern Argentario promontory, the Triassic Verrucano clastic deposits unconformably overlie weakly metamorphosed grey and black sandstone, which alternates with prevalent, black, carbonate shales (Argentario Sandstones; Fig. 3). Scattered conglomeratic and quartzitic layers also occur. Vai (1978) pointed out the local presence of crinoid remains and suggested a shallow marine environment for these deposits. The age has been tentatively identified by Lazzarotto *et al.* (1964), and by Gasperi & Gelmini (1973), as Late Carboniferous. Further East, in the nearby Romani Mts., prevalent sandy, phyllitic, monotonous rocks, generally referred to as Carboniferous and/or Permian, crop out again beneath the Verrucano *s.l.* (Cocozza *et al.* 1974; Gasperi & Gelmini 1975; Azzaro *et al.* 1976). However, according to Meccheri (*in* Conti *et al.* 1991), these rocks were probably affected by the Hercynian Sudetian phase.

Widespread and thick Paleozoic sequences are also present in several deep wells in the geothermal fields of central-southern Tuscany. In the Larderello area, Elter & Pandeli (1990) related a series of dark, grey-black phyllites, with quartzitic intercalations, to the Upper Carboniferous deposits present elsewhere in the region ("San Lorenzo Group" *in* Bagnoli *et al.* 1979). Southeast of Mount Amiata, in the Piancastagnaio area, the Triassic Verrucano overlies 2000 m of graphite-rich phyllites, metasandstone and metagraywackes (formation A, Elter & Pandeli 1991), which locally yield crinoids, brachiopods, calcareous algae and other fossil remains. They may be correlated to the turbiditic Farma Formation of the Monticiano-Roccastrada massif, which was identified by Cocozza *et al.* (1987) as late Bashkirian-Moscovian in age.

In light of the above, the Late Carboniferous picture of the Apennine continental domains shows no evidence of intense magmatic activity. By contrast, this activity was consistently present in the Alps and the "Calabro-Peloritan Arc". Moreover, it is worth mentioning that in southern Calabria, as in the Ivrea Zone, mafic-igneous, basic bodies occurred, around 300 Ma, during a granulite-facies metamorphism.

PERMIAN

The Permian System of the continental domains under discussion may be, for the most part, divided into two groups or cycles. The lower cycle, which is connected with the previous one of Late Carboniferous age, consists of prevalent detritic and volcanic deposits, whereas the upper cycle generally includes the Verrucano-Val Gardena red clastics. However, the Apenninic Verrucano pertains to Triassic times. Moreover, a marked unconformity, which is associated with a gap of uncertain duration, separates the lower group from the stratigraphic cover.

Southern Alps

In the South Alpine region, the lower group is made up of calcalkaline, intermediate and acidic volcanics which alternate, in some strike-slip or pull-apart basins (Cassinis & Perotti 1994), with alluvial and lacustrine siliciclastic deposits. Intrusive, largely calcalkaline granitoid rocks, which are concentrated in the area west of Lake Maggiore and along and near important tectonic lines (*e.g.* the Giudicarie, Pusteria and Valsugana lines), are also attributed to the same igneous activity. From west to east, the Biella-Valsessera, Alzo-Roccapietra, Mottarone-Baveno, Montorfano, Cuasso al Monte, Val Biandino, Mt. Sabion, Mt. Croce, Ivigna, Bressanone and Cima d'Asta plutonic masses represent the best-known examples, and generally have an intrusion age of around 275 Ma. Moreover, in the western South Alpine sector, it is worth noting that calcalkaline mafic-to-intermediate bodies intruded before, during and after the granite batholith emplacement of the so-called "Serie dei Laghi", which is tectonically juxtaposed to the lower crustal Ivrea-Verbano Zone (Giobbi Origoni *et al.* 1988). Among these bodies, an appinitic suite predates the uplift and erosion of the Hercynian belt and the intrusion of the granite plutons (Boriani *et al.* 1988).

In the Bolzano-Trento and Varese-Lugano areas, the igneous, extrusive cover is generally represented by voluminous sequences of up to 1500-2000 m in thickness. On the basis of an idealized stratigraphic succession (Di Battistini *et al.* 1988), the Bolzano-Trento southern plateau is divided from base to top into:

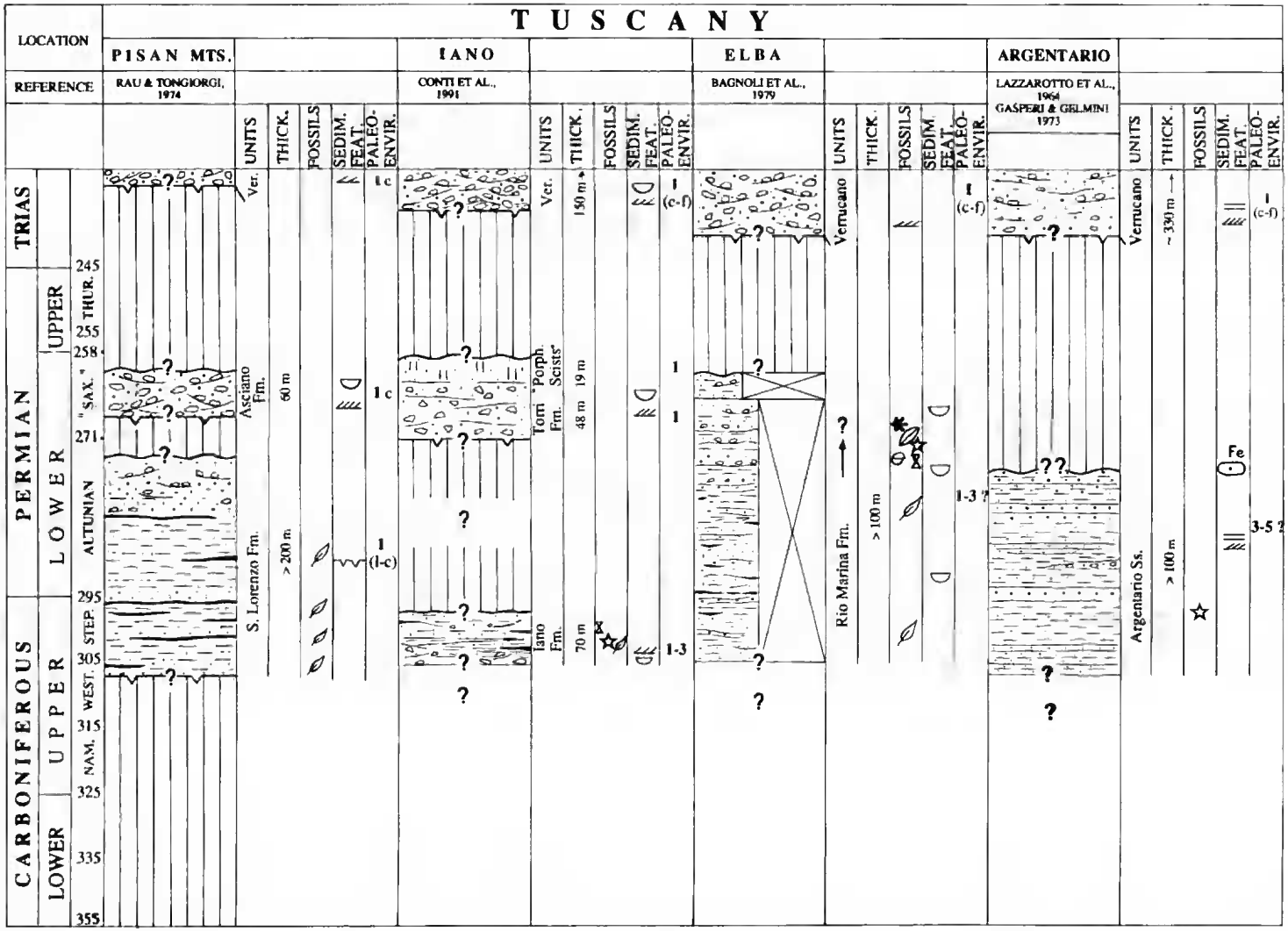


FIG. 3. — Some selected and schematic Upper Carboniferous-Permian stratigraphic successions in the Tuscan areas. Localities and legend in figures 1, 2 respectively. Vertical distances not time or thickness-related. Geologic time scale from Odin & Odin (1990).

1. A "Lower Group" composed of (basaltic) andesitic lavas, trachyrhyolitic lavas, rhyodacitic ignimbrites, dacitic-rhyodacitic lavas and, again, andesitic lavas.
2. A more homogeneous "Upper Group" comprising rhyodacitic ignimbrites, dacitic-rhyolitic lavas, and rhyolitic ignimbrites (Fig. 2).
Early Permian volcanism is indicated by Rb-Sr biotite isochron, which ranges from 276 ± 2 Ma to 267 ± 2 Ma (Barth *et al.* 1993), and by congruent biotite model ages estimated from rhyodacitic ignimbrites in the Lower and Upper Groups (D'Amico & Del Moro 1988), and rhyolitic ignimbrites in the Upper Group (D'Amico *et al.* 1980).
The igneous, effusive, calcalkaline succession of the Ganna area, near Varese, is made up, from base to top, as follows (Bakos *et al.* 1990):
1. Rhyodacitic and rhyolitic tuffs which are intercalated with rhyolitic ignimbrites; the upper part consists of alternating layers of clastics;
2. Clastic and syn-volcanic epiclastic rocks (mainly composed of occasionally thick pyroxene-biotite bearing, andesitic to dacitic lava flows) with overlying rhyodacitic tuffs and rhyolitic ignimbrites with tuffs;
3. Tuffs, ignimbrites and lavas of rhyolitic to rhyodacitic composition.
In the Varese-Lugano area, the top of the aforementioned leucogranitic Cuasso al Monte or Ganna stock intrudes into this section. Hunziker & Zingg (1980) suggested, on the basis of available Rb-Sr whole-rock isotope data on some rhyolitic volcanites of the Val Sesia and Lugano region, that the volcanic activity occurred some 278 ± 3 Ma ago. Moreover, Stille & Bulletti (1987) pointed out that the best age estimate of the Lugano volcanites is given by a Rb-Sr mineral isochron of 262 ± 1 Ma
Generally speaking, the hypothesis of an Early Permian and, in some places, a Latest Carboniferous interval for this post-orogenic volcanism, agrees fairly well with the available paleontological data coming from the intervening sedimentary basins, *i.e.* the well-known fossiliferous Orobic, Collio and Tregiovo fault-bounded basins of the central South Alpine (Fig. 2). However, the macro and microfloral assemblages of the typical Collio and Tregiovo beds, especially the ones pertaining to the latter unit, generally enable us to attribute them to late Early Permian and early Late Permian times (see the Remys and Doubinger *in* Cassinis *et al.* 1995; Fig. 2). In particular, the palynomorphs recognized in the Tregiovo Formation, which include *Lueckisporites virkkiae*, *Corisaccites alutas*, *Crucisaccites varisulcatus*, *Paravesicaspora splendens* and other forms, would seem to indicate the presence of Upper Permian, including the Kazanian deposits. Therefore, the overlying, calcalkaline, rhyolitic ignimbrites appear to testify that the volcanic activity of this area (and probably of a vast part of the South Alpine segment) ended during younger Permian times, before the deposition of the pre-Triassic Verrucano Lombardo and of the more or less coeval Val Gardena Sandstone. Within a general stratigraphic framework, the more recent investigations on the tetrapod footprints found in these basins (Ceoloni *et al.* 1987; Conti *et al.* in press) also concord with this dating.
Therefore, in the South-Alpine segment, the Verrucano-Val Gardena redbeds, which unconformably overlie the above-mentioned deposits and step down onto the Hercynian basement, pertain to the Upper Permian younger cycle. This clastic lithosome is generally missing from Lake Como to the western extremity of the chain.

Western Alps

Along the western Alps, the Hercynian basement of the lower Austroalpine domain underwent a Permo-Carboniferous HT-LP metamorphism that was due to a geothermal anomaly, which in turn was caused by the asthenoshere upwelling and gave rise to granulitic facies. This substrate includes gabbros and granitoids, whose ages are not always well defined, which crop out in the Dent Blanche (Matterhorn gabbro, *c.*250 Ma; Dal Piaz *et al.* 1977) and other nearby smaller klippens. Sediments and volcanics below the Upper Permian Verrucano clastics, as well as (late)-postHercynian granitoids, have also been indicated in some Pennine areas of the chain.
In the Ligurian Alps, the present pre-Piedmont Zone (Fig. 2) is locally characterized by the Lower Permian, mera-volcaniclastic Aimoni Formation of the Melogno "porphyroid" Group,

which is unconfotmably capped by the younger pre-Triassic Verrucano. At the same time, the Briançonnais area (Fig. 2) was affected by widespread, thick, calcalkaline, rhyolitic and subordinate rhyodacitic ignimbrites, together with pyroclastics (the so-called afore-mentioned Melogno porphyroids); in the uppermost part, however, Cabella *et al.* (1988) found evidence of the onset of a sub-alkaline potassic composition in the Ormea area. In the Helvetic (Dauphinois-Provençal) Zone of the Argentera massif, the Permian continental deposits are extensively developed, with a thickness of almost 2000 m on the French slope.

In the western Alpine domain, the above-mentioned deposits of the lower cycle are unconformably overlain by the Verrucano clastics of the Upper Permian cycle.

Apennines

According to Bagnoli *et al.* (1979), Permian volcanism probably occurred in the western Apuane Mts. of Tuscany, as indicated by rhyolitic clasts in the basal part of the Middle Triassic Verrucano. This magmatic activity is also supported by the presence of some granitic blocks (308 ± 10 Ma to 287 ± 10 Ma, Eberhardt *et al.* 1962) inside the Ligurian allochthonous structural units. These units have been interpreted as crustal fragments, partially derived from the Tuscan continental margin (Elter *et al.* 1966).

Further south, in some areas of the Pisan Mts., there are red breccias and conglomerates, the so-called Asciano Formation, which are up to 80 m thick and of undefined age. These clastics, interpreted as scarp-foot alluvial deposits (Rau & Tongiorgi 1974), lie either on the San Lorenzo Formation or directly on the Hercynian metamorphic basement (Fig. 3). The presence of red, rhyolitic clasts in the overlying, basal Verrucano, a feature not previously observed in the Asciano Formation, suggests that volcanism was probably active during Permian times, after the Asciano was deposited, but before the Middle Triassic Verrucano.

South of the Arno River (Fig. 3), massive polygenic detrital deposits (Torri Formation) and porphyric products (partly interpreted as acidic volcanics) overlie the Iano Formation. Although the dating of both units is uncertain, it is likely that the porphyric products are Permian. The Triassic Verrucano crops out unconformably above this section, with intermediate, purple, carbonate-bearing siltstones occurring locally.

In the Larderello geothermal area, the presence of clastic units, such as the Mts. Pisani Asciano Fm. and the redbeds (including clasts of acidic volcanics) of the so-called Castelnuovo Sandstone, which resembles the Val Gardena Fm. of the Dolomite Alps, seems to indicate a wider Permian continental domain. Moreover, in the Mount Amiata geothermal field, below the Triassic Verrucano, wells reveal a Paleozoic, metamorphic and tectonised clastic sequence, where a carbonate level with Late Permian fusulinids, such as *Praeparafusulina* cf. *lutigini*, *Polydiexodina* (*Eopolydiexodina?*) cf. *shabalkini*, *Cancellina* sp., *Parafusulina* sp., *Pseudofusulina* sp., etc., occurs at the transition between the so-called formations A e C (Elter & Pandeli 1991). According to Pasini (1991), the whole association indicates the *Cancellina* Zone (Kubergandian); in addition, the presence of *Praeparafusulina* links this finding to that of Bodechtel (1964) in the Island of Elba, and also to the Artinskian of the Southern Alps. Thus, from the above it may be hypothesized that a great part of formation C (about 700 m drilled) is Permian in age (Conti *et al.* 1991).

On the Island of Elba (Fig. 3), the upper part of the Rio Marina Formation, which includes alluvial-deltaic and marine sediments with *Parafusulina* sp., belongs to the Early Permian. Continental, clastic deposits, beneath the Triassic Verrucano, have also been attributed, at least partially, to the same age in the Argentario and Romani Mts. (Fig. 3).

Farther east, in southern Tuscany, between the Montagnola Senese and Mt. Leoni, the Upper Paleozoic sequence is essentially characterized by the presence of marine conditions.

In the southern Apennines (Basilicata), mainly Upper Permian (Murgabian-Dzhulfian *s.l.*) carbonate clastics occur in the lower part of the Triassic Mt. Facito Formation. A continental regime at the end of the Permian (Dorashamian) may be presumed, as we have no data to prove otherwise.

The "Calabro-Peloritan Arc", which is the result of at least six different composite microplates of a former Hercynian basement (Vai 1991), reintroduces continental domains. The metamorphic substrate was generally intruded by granitoids; however, a Permo-Carboniferous cover is lacking or unknown. In the Longobucco structural block, granodiorites and younger Al_2SiO_5 - bearing granites, of 284 ± 14 Ma (Wieland 1978) occurred before the deposition of Verrucano-type red clastics, referred to by Baudelot *et al.* (1988) as the top of the Triassic. To the south, near Rovale, gabbroic and dioritic bodies with Rb-Sr biotite cooling ages of 270-280 Ma (Caggianelli *et al.* 1991), as well as other close granodioritic rocks, are cut by porphyritic granitic dikes and plugs. According to Campana *et al.* (1991), in the Serre-Capo Vaticano areas, the radiometric age-datings of calcalkaline granitoids, which range from tonalites to granodiorites-monzogranites, with minor quartz diorites/gabbros, have been estimated as approximately 270-291 Ma. In the Aspromonte block, the time-span of some peraluminous intrusions within the Hercynian metamorphic basement ranges between 282 and 286 Ma (*in* Spalletta & Vai 1990).

In the above-cited areas, the sediments related to the Verrucano belong to the Triassic. The Tuscan deposits lie unconformably on those of the lower cycle, or step down directly over the Hercynian metamorphic substrate, and are generally ascribed to Mid-Triassic times. Although the Apenninic Verrucano is not generally as young as the Carnian, recent dating of the Longobucco and Longi Verrucanoes in the "Calabro-Peloritan Arc" as latest Triassic (Baudelot *et al.* 1988) places an ourside limit on the diachronism of the deposit.

Sicily

In north-east Sicily, the Mts. Peloritani block includes some granitoids, which date from 293 ± 9 Ma, and are situated within a strongly deformed crystalline substrate and below a Triassic Verrucano-like clastic unit (*in* Spalletta & Vai 1990). As in Basilicata, the western sector of the island displays highly fossiliferous Permian marine deposits, the basement of which is unknown.

GENERAL REMARKS

In the record of continental domains in Italy from Carboniferous through to Triassic we can recognize several sedimentary and/or tectonic cycles as well as other events.

In some Alpine regions a first main cycle began in the Late Carboniferous, where it is documented by the Westphalian-Stephanian deposits of the Como-Maggiore area, of the western Liguria (Viozene) and of other localities. This cycle continued, in a seemingly more widespread fashion, into various levels of the Permian, up to the onset of the so-called Verrucano rock-units, which belong to the upper part of this System.

In some places of the central South Alpine sector, as in the Collio and Tregiovo basins, the macro- and microfloras present generally enable us to attribute the above cycle to the late Early Permian and, in particular regarding the Tregiovo beds, also to slightly younger Late Permian times. However, as the Permo-Carboniferous sedimentary and volcanic succession of the Alpine region is subjected to consistent and rapid geometric changes, it is problematic and often impossible to achieve extensive correlations of the local data. Further difficulties arise owing to the presence of stratigraphic discontinuities. These unconformities are not only confined to the boundaries of this lower cycle but also occur inside its vertical and lateral development, and mark the presence of gaps of various but as yet unknown time-duration.

As indicated earlier, in the Alpine continental areas, the Verrucanoes and, to the east, the more or less coeval Val Gardena Sandstones (together with some underlying conglomeratic units, such as the Daone Cgl. in the Giudicarie area) mark the beginning of another Permian upper cycle. Palaeontologic data (plants, palynomorphs, tetrapod footprints) and the stratigraphic position of the Val Gardena redbeds, which pass laterally and vertically to the Upper Permian shallow-marine Bellerophon Formation, generally ascribe the above units to Late Permian. The overlying Lower Triassic Werfen Formation and its lateral equivalents unquestionably confirm this attribution.

In the Tuscan Apennines, the stratigraphic

schemes and other data in the text indicate the persistence of the aforementioned older cycle. However, as in Iano and Elba, the continental deposits show some Late Carboniferous to Early Permian shallow-marine intercalations, which testify to a former irregular landscape of the region. Moreover, the Upper Permian cycle has not, as yet, been recorded in this area. According to the stratigraphic successions of figure 3, the Verrucano deposits essentially developed during Middle Triassic times. As a consequence, the presence at Pta Bianca, near La Spezia, of prevalent Anisian and Ladinian marine deposits (Martini *et al.* 1986; Passeri 1988), which rest unconformably over the Hercynian crystalline basement, leads us to relate the overlying Appenninic Verrucano to a cycle evolution which does not coincide with that of the Alpine region.
In figures 2, 3, the contact between the two indicated cycles or groups deals with tectonic, paleogeographic and probably paleoclimatic variations. Structural highs and lows during the older cycle were formed in the context of a prevalent tectonic transcurrent regime (see Arthaud & Matte 1975; Vai *et al.* 1984; Ziegler 1984; Massari 1988; Rau 1990; Cassinis & Perotti 1994; and others) which, during the younger cycle, changed into a more pronounced extensional framework. Moreover, in the South Alpine area the second cycle led to a complete extinction of the (late)-postHercynian volcanic activity.
Erosion during the formation of the Verrucano and Val Gardena deposits generally caused progressive flattening of the landscape, and this ultimately favoured a decisive transgression of the sea. However, the shallow-marine intercalations in some Stephano-Autunian rocks (Iano, Elba) of the northern Apennines demonstrate the relative proximity of this sea from Latest Carboniferous-Early Permian times, and indicate a general provenance from the east. These incursions reached north to the Carnic Alps, where the post-Westphalian succession of the lower cycle was persistently characterized by marine conditions.
South of Tuscany, the particular geological scenario of the "Calabro-Peloritan Arc", which is rich in the pre-Triassic plutonics but lacks a mid-Carboniferous-Permian sedimentary cover, probably derived from a group of lands in front of the Corsica-Sardinia block, but differently situated, and seemingly affected by a mosaic of deeper structural levels that were later exhumed by the Alpine cycle.

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